Radiation hardness of the PSD APDs for the CBM experiment*

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The projectile Spectator Detector (PSD) of the CBM experiment is designed to register forward spectator nucleons and fragments emitted in nucleus-nucleus collisions at very low polar angles. It will be used to determine the collision centrality and the reaction plane orientation.

The PSD is a fully compensating modular lead-scintillator calorimeter. The Avalanche Photo-Diodes (APD) are used to read out the scintillation light via wavelength shifting fibers. An important characteristic of the APD is its radiation hardness to a neutron fluxes of 10^{13} n/cm^2 which corresponds to two months of CBM experiment operation.

Two different APD samples, Ketek PM3375 and Zecotek MAPD-3N, were irradiated at the NPI Řež Cyclotron Facility by quasi-monoenergetic secondary neutron beam with energy of 35 MeV. A sample of Zecotek APD was irradiated with a dose of $3.4\pm0.2\ 10^{12}$ n/cm^2, while two samples of Ketek APDs were irradiated with $2.5 \pm 0.2\ 10^{12}$ n/cm^2. Doses were measured with a special PIN diode calibrated with a dose equivalent to 1 MeV neutron [1]. The operation temperature during the tests was kept at $22 \pm 0.5°$ C.

The APD characteristics were measured before and after the irradiation. The Capacitance-Voltage (C-V), Current-Voltage (I-V), and Capacitance-Frequency (C-F) characteristics were studied using dedicated testing setup at NPI Řež [2,3]. After irradiation, the C-V technique showed significant decrease of hysteresis and fast but not complete self-annealing. The I-V curve revealed about 1000 times increase of dark current after irradiation. The C-F study showed significant increase of short-living traps in Silicon. The test results suggest an increase of internal APD noise, especially of the high frequency, which dependents on the amount of short-living traps in the APD volume.

Figures 1 (2) show the results of the Ketek (Zecotek) APD tests with LED and cosmic muons. Both APDs have a maximum signal (noise) amplitude of about $0.3 - 0.4$ V (0.05 V) which corresponds to $20 - 30$ ph.e (3 ph.e). After irradiation both APDs are unable to resolve single photons due to high noise levels. This is not critical for the PSD performance since there are at least 15 ph.e. produced in one PSD module already by a cosmic muon. The signal and noise peaks for irradiated Ketek APD are very close which makes it very difficult to separate signal from noise. On a contrary, signal and noise peaks for Zecotek APDs are well separated from each other, what allows reliable signal from noise separation even after irradiation.

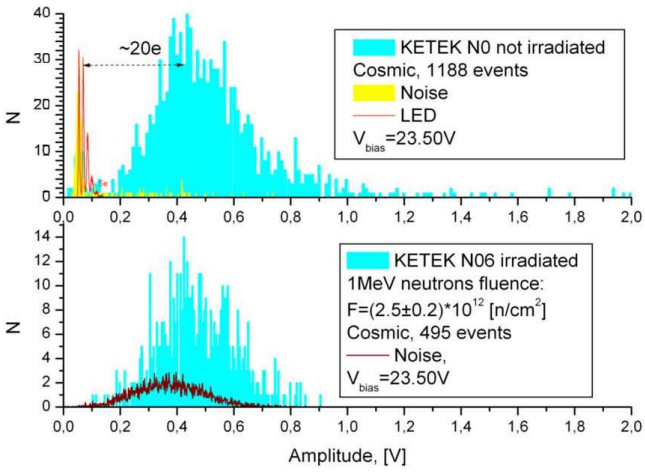

Figure 1: Test results with LED and cosmic muons of Ketek APD before (upper) and after (lower) irradiation.

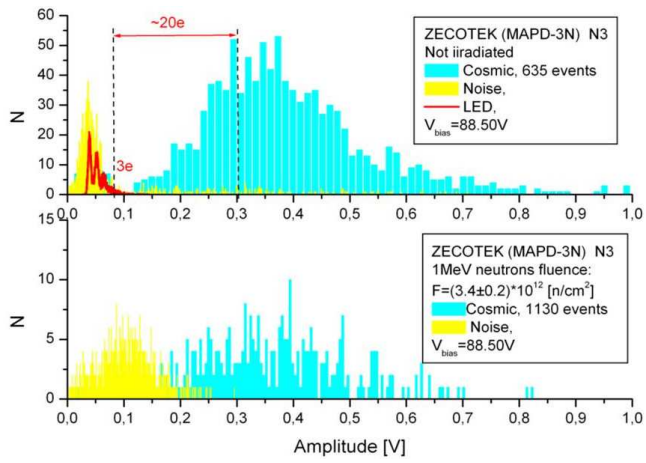

Figure 2: Test results with LED and cosmic muons of Zecotek APD before (upper) and after (lower) irradiation.

References

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